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Loblolly and slash pine control organic carbon in soil aggregates and carbon mineralization

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ABSTRACT

The influence of soil aggregation as a means to protect soil organic carbon (SOC) from mineralization is unclear in very sandy soils. The dominant forest cover types in the Lower Coastal Plain of the US where sandy surface soils prevail are loblolly pine (*Pinus taeda*) and slash pine (*Pinus elliottii var elliottii*). The purpose of this study was to investigate the role that aggregation plays in C incorporation and sequestration in very sandy soils of the Lower Coastal Plain found under loblolly and slash pine ecosystems. Thirteen forest stands (seven loblolly pine; six slash pine) were used for this investigation. A sonic dismembrator was used to apply dispersive energy in order to destroy aggregates. The use of sonic energy was shown to be a valid tool for studying aggregates in sandy soils. The data showed that aggregates do not protect ASOC from mineralization in these very sandy soils. Loblolly pine surface mineral horizons accumulated 131% more TSOC than slash pine soil horizons. Slash pine soils had a 27% higher specific mineralization rate than loblolly pine soils; and Diffuse Reflectance Fourier Transform spectra (DRIFTS) showed that soils under loblolly pine were more aromatic than those under slash pine – and became more aromatic as mineralization proceeded. Due to their dominance in the Lower Coastal Plain of the US, pine ecosystems play an important role in the conversion of atmospheric CO_2 into the TSOC pool. However, soil aggregation should not be considered a mechanism to protect SOC in these very sandy soils when modeling soil carbon dynamics, even though slash pine systems show a slightly greater capacity to develop aggregates.

1. Introduction

Soil aggregation reduces erosion, improves water infiltration, and protects aggregate soil organic carbon (ASOC) from mineralization (Lal et al., 1997). Yet one relevant question is whether the protection function is equally true for all soil textures. The ASOC is protected physically, chemically and physiochemically (Golchin et al., 1994; Blanco-Canqui and Lal, 2004), with ASOC turnover rates appearing to be faster in macroaggregates than microaggregates. According to Besnard et al. (1996), Franzluebbers and Arshad (1997) and Sainju et al. (2003), this suggests greater protection of ASOC by microaggregates. Wild (1988) further suggested that ASOC in microaggregates may also be better protected if it is more biochemically recalcitrant. These observations have resulted in the commonly held belief that the C storage provided by macroaggregates is greater in quantity but transient in terms of physical protection compared to microaggregates (Tisdall and Oades, 1982).

The ability of soils to physically protect soil C through aggregation appears to be partially dependent on soil texture. Residence times of ASOC in macro and microaggregates differ depending on the physiochemical attraction between mineral and organic particles, and the location of the organic material within the aggregates (Emerson, 1959). Buyanovsky et al. (1994), working with a silt loam soil under soybean cultivation, found that turnover rates of ASOC were 1–3 years for macroaggregates and approximately 7 years for microaggregates. Conversely, Skjemstad et al. (1990) found no remarkable difference between the ASOC turnover rates of macro and microaggregates in an Australian sandy soil. Christensen (1987), working with loamy sand and sandy loam soils noted no physical protection of ASOC due to aggregation. This evokes the question: what level of physical protection does ASOC have in sandy soils?

Aggregate dispersive energy (ADE) has been used to characterize aggregate strength in a variety of soils. One assumes that ADE relates to ASOC protection; however, the relationship between ADE and C mineralization within aggregates has been poorly

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studied. Aggregate dispersion energy curves (ADEC) have been used to examine aggregate strength and determine the quantity of C in aggregates held at different dispersion energies. The ADEC method has the potential to quantify the ASOC that is physically protected (North, 1976; Christensen, 1992; Cambardella and Elliot, 1993; Six et al., 2001; Swanston et al., 2005; Sarkhot et al., 2007a). One method of dispersing aggregates uses sonic energy (Sarkhot et al., 2007a), yet there have been no studies that document the degree of aggregate dispersion via sonic vibrations.

As mentioned above, sandy soils have been studied for their amount and properties of micro and macroaggregates, yet their ability to protect ASOC has been poorly documented (Sarkhot et al., 2007a). Sandy surface soil horizons dominate in the Lower Coastal Plain of the Southeastern US. These and associated flatwood soils make up 25% of the land base of Florida (Zelazny and Carlisle, 1971) or over 3.4 million ha. Sarkhot et al. (2007a,b), presenting the only ADECs published for Lower Coastal Plain soils, demonstrated that these very sandy soils (less than 5% clay) were well aggregated, showed a hierarchical aggregate structure, and showed that they held as much as 40% or more of the total soil organic carbon (TSOC) as ASOC. However, no information exists on the stability of ASOC relative to ASOC mineralization for these important agricultural and forested soils.

Fourier Transform Infrared Spectroscopy (FTIR) has been useful in investigating soil organic carbon changes due to soil management and land use changes. Ellerbrock and Kaiser (2005) showed that crop and site conditions controlled the chemical signature of organic matter fractions. Sarkhot et al. (2007a) used a form of FTIR, Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS), on a soil similar to the one used in this study to identify TSOC chemical differences in different soil size fractions and TSOC changes due to dry and wet sieving. DRIFTS should be a useful measure in evaluating TSOC and ASOC chemical fingerprints.

The purpose of this study was to investigate the role that aggregation plays in C incorporation and sequestration in very sandy soils of the Lower Coastal Plain found under loblolly and slash pine ecosystems. This was addressed by focusing on four objectives: (i) validation of a sonication method for determining ADECs; (ii) comparison of TSOC incorporated into aggregates of the sandy surface horizon of loblolly and slash pine ecosystems; (iii) examination of the relationship between ADE and TSOC and ASOC accumulation and mineralization for loblolly and slash pine ecosystems, and (iv) identification of TSOC chemical characteristics via DRIFTS that explains differences in TSOC stability and mineralization.

2. Methodology

2.1. Experimental sites and field sampling

The experimental sites and samples from these sites were chosen from a previous stratified random sampling study which was geared toward developing a soil carbon inventory of the state of Florida based on 1000 sampling points throughout the state. The study area used for this research was National Resource Conservation Service – Conservation Area 2 located in North Florida. From the original set of 55 forest stand locations in this Conservation Area, 13 sites were selected. Seven sites supported loblolly pine (*Pinus taeda* L.) ecosystems and 6 sites supported slash pine (*Pinus elliottii* var *elliottii* Engelm.) ecosystems. Originally seven slash pine sites were selected but it was later found that one site was misclassified, so it was removed from the data set. The sites were chosen so that they had similar soil C means and the ranges that were characteristic of the original set of 55 locations. The TSOC means and ranges were 1.06% and 4.01% for slash pine sites and 2.45% and 1.17% for loblolly pine sites. A soil sample from the surface 20 cm of mineral soil was collected at each sampling location by combining four 30 × 5.8 cm cylindrical cores (McIntyre, 1974). Soils were then air-dried and sieved to pass a 2 mm screen.

Sampling sites were located in the North Florida counties of Alachua, Citrus, Clay, Duval, Flagler, Lafayette, St. Johns, Putnam, Taylor, and Volusia. The climate of the region is hot and humid with an average yearly precipitation of 113 cm, and yearly average minimum and maximum temperatures of 14 °C and 27 °C (Southeast Regional Climate Center, 2007). The sampling sites represented Flatwood landscapes which are somewhat poorly to poorly-drained with a seasonally high water table.. Because the sites were randomly selected from all possible sampling points in the conservation area, the past history of each is unknown. However, because of the sampling scheme, these sites are representative of field conditions in the Conservation Area. All soils but one were Spodosols represented by the Suborder, Aquod (Table 1). Loblolly and slash pine ecosystems had a common understory of saw palmetto (S. *Serenoa repens Small*), wax myrtle (*Myrica cerifera* L.), gallberry (*Ilex glabra* L.), brackenfern (*Pteridium aquilinum* L.), blackberry (*Rubus sp.*), and fetterbush (*Lyonia lucida* Lam.). Various grasses were common, such as bluestem (*Andropogon virginicus* L.) and wiregrass (*Aristida beyrichiana*). Perennial woody species included young oaks (*Quercus sp.*), sweetgum (*Liquidambar styraciflua* L.), bays (*Persea sp.*), and Florida maple (*Acer barbatum*). One loblolly and one slash pine site were natural pinelands following disturbance; while the remaining were under plantation management. All stands were 8–15 years in age.

2.2. Laboratory methods

2.2.1. Experiment 1. Testing of the sonication method

The sonication method used to develop aggregate dispersion energy curves (ADEC), as defined by Sarkhot et al. (2007a,b), was tested on each soil size fraction. The purpose of this experiment was to assure that sonication resulted in aggregate dispersion. The evaluation was done on three soil size fractions. These size fractions were consistent with those used in other studies (Oades and Waters, 1991; Roscoe et al., 2000; Six et al., 2001; Sarkhot et al., 2007a). One 100 g soil sample from the surface of a Spodosol, similar to the sampling sites in this study, was dry-sieved through a horizontal mechanical shaker for 5 min at 75 rpm using 53, 150, and 250-μm sieves (Sarkhot et al., 2007a). Therefore, the resulting size fractions used in this study were 2000–250, 250–150, and 150–53 μm. The less than 53 μm fraction was not used.

The ADEC for each size class sample was constructed by the method of Sarkhot et al. (2007a,b). Six, 5-g samples of each size class were placed into glass beakers with 100 mL of deionized water. Each of the 5-g sample was exposed to a unique, increasing energy level (0–200 J mL^{-1}). Using a sonic dismembrator (Fisher Scientific, Model 500, Hampton, NH), the sonic probe was immersed 10 mm below the surface of the suspension. Energy levels were applied by using a range of amplitude (20–69%) and time (1–7 min) combinations. A correction factor was applied to the energy levels, as described by Sarkhot et al. (2007a), to adjust the readings for energy absorbed by the water and lost as heat. Temperature rise was minimized by a pulse method (60 s on and 30 s off, Sarkhot et al., 2007a). In this manner aggregates in each size fraction were incrementally disrupted. After disruption, each sample was passed through the same-sized sieve used to obtain the size fraction. The SOC remaining on the sieve after each sonication represented particulate SOC and ASOC that resisted dispersion. The SOC passing through the sieve was considered the ASOC that was dispersed by sonication. Sieve retentates were dried in a forced-air oven at 65 °C. Three 0.1 g subsamples of the oven-dried retentates were placed under a microscope and the numbers of aggregates were counted with the help of a 1 cm × 1 cm grid system.